

Progress report for year 2 (October 2004-September 2005)

Proposal: GC04-072

Title: Regional Climate Data Assimilation System (R-CDAS) and NAME Data Impact and Prediction Experiments

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Project duration: April 2004- March 2007

I. Accomplishments

1) RCDAS:

- RCDAS has been in operation at the Climate Prediction Center from April 2004 to the present. The daily data with both the merged files and a subset of land surface properties are distributed through the NOMAD7.
- We discovered an error in the RCDAS/RR from 1 January 2003- 1 May2005. The CMORPH data were not read in correctly. This does not impact analyses over the United States, but will influence analyses over Mexico and the adjacent oceans. We have already started to rerun the RCDAS for this period. We should be able to complete this by the end of 2005. The correct data are also distributed through the NAMOD 7.

2) Data Impact studies for the NAME EOP period

We have started to perform the NAME data impact experiments using one global system (CDAS2), and two regional systems: the RCDAS and the 12-km EDAS systems.

The EDAS experiments were not proposed in the original proposal. Because the impact of the NAME soundings is largely regional, we decided to perform the EDAS experiments. The purpose is to examine whether the data impact depends on the model resolution.

For each system, we will perform three experiments. They are performed with the same model and data assimilation system. Three experiments differ in the input data:

- (1) DASw :with all NAME04 special soundings included ,
- (2) DASwt: with all NAME04 soundings excluded;
- (3) DASwtmex: with only sounding data over the northern Mexico and the Southwest excluded.

The soundings and frequencies are listed in Table 1. The comparison among these experiments indicates the impact of the NAME 04 soundings on the NCEP data assimilation systems.

These experiments were completed: CDASw, CDASwt, CDASwtmex, EDASwtmex, RCDASw, RCDASwt and RCDASwtmex. Results will be reported in the special J. Climate issue on the NAME. Data will be distributed through the NOMAD system.

3) Improve summer seasonal precipitation simulations over the United States and Mexico

- Examine the impact of initial conditions on summer precipitation forecasts;
- Identify the shortcomings of the land surface model in the GFS.

II. Detailed description of each element

1. RCDAS

RCDAS have been in operation since April 2004 and it will continue. The data are distributed through the NAMAD7. We have a plan to use the RCDAS products to support the drought monitoring.

2. DATA impact study

During the North American Monsoon Field Campaign (NAME04) extensive observational period (EOP) from 1 July 2004-15 August 2004, special soundings were in operation. The sounding locations and frequency are listed in Table 1. During the IOP periods, some soundings were reported 6 times per day. That gives us an opportunity to study the sounding impact on diurnal cycle. We have performed three experiments based on both the CDAS2 and the RCDAS systems: (1) with all soundings included, (2) with all soundings excluded and (3) with soundings over northern Mexico and the Southwest excluded. Because most soundings were accepted by the operational NCEP experiments, we also archived and examined the operational NCEP data assimilation products for the EOP period.

a) CDAS

For the global CDAS2, the impact is largely regional and is concentrated over the northern Mexico. There are very little differences in upper level jet streams or large scale circulation anomalies. There are improvements on rainfall 6 hr forecasts. Figure 1 shows the 6hr precipitation (P) forecasts during the assimilation cycle averaged over the EOP period, which should be compared with the gauge analyses during the same period

Table 1: The NAME04 soundings and frequencies.

Site	Elevation (m)	Latitude	Longitude	Dates	EOP Freq (samples/day)	IOP Freq (samples/day)
P. Penasco (ISS)*	48	31.18N	113.33W	7/1 - 8/15	2	4
Kino Bay (ISS)*	4	28.81N	111.93W	7/1 - 8/15	2	4
Los Mochis (ISS)*	4	25.41N	109.05W	7/1 - 8/15	4	6
Loreto (GLASS)*	15	26.01N	111.21W	7/1 - 8/15	4	6
Empalme (SMN)*	12	27.95N	110.77W	6/21-8/31	2	6
Mazatlan (SMN)*	4	23.20N	106.42W	6/21-8/31	2	6
Chihuahua (SMN)*	1434	28.63N	106.08W	6/21-8/31	2	6
Torreon (SMN)*	1150	25.53N	103.45W	6/21-8/31	2	6
Monterrey (SMN)	448	25.87N	100.23W	6/21-8/31	2	6
Zacatecas/Guadalupe (SMN)*	2265	22.75N	102.51W	6/21-8/31	2	6
La Paz (SMN)*	19	24.17N	110.30W	6/21-8/31	2	6
Tucson (NWS)*	788	32.12N	110.92W	6/21-8/31	2	4
Las Vegas (NWS)	1007	36.62N	116.02W	6/21-8/31	2	4
San Diego (NWS)	132	32.85N	117.12W	6/21-8/31	2	4
Flagstaff (NWS)	2179	35.23N	111.82W	6/21-8/31	2	4
Albuquerque (NWS)	1619	35.05N	106.62W	6/21-8/31	2	4
El Paso (NWS)	1252	31.87N	106.70W	6/21-8/31	2	4
Amarillo (NWS)	1094	35.23N	101.70W	6/21-8/31	2	4
Midland (NWS)	873	31.95N	102.18W	6/21-8/31	2	4
Del Rio (NWS)	314	29.37N	100.92W	6/21-8/31	2	4
Yuma (ARMY)*	147	32.51N	114.00W	7/1-8/15	2	4
Phoenix (SRP)*	384	33.45N	111.95W	6/21-8/31	2	4
Belize City, Belize	5	17.53N	88.3W	7/20 - 9/15	2	-
San Jose, Costa Rica	939	9.98N	84.22W	6/16 - 9/9	4	-

* indicates that the station is not included in the DASwtmex experiments

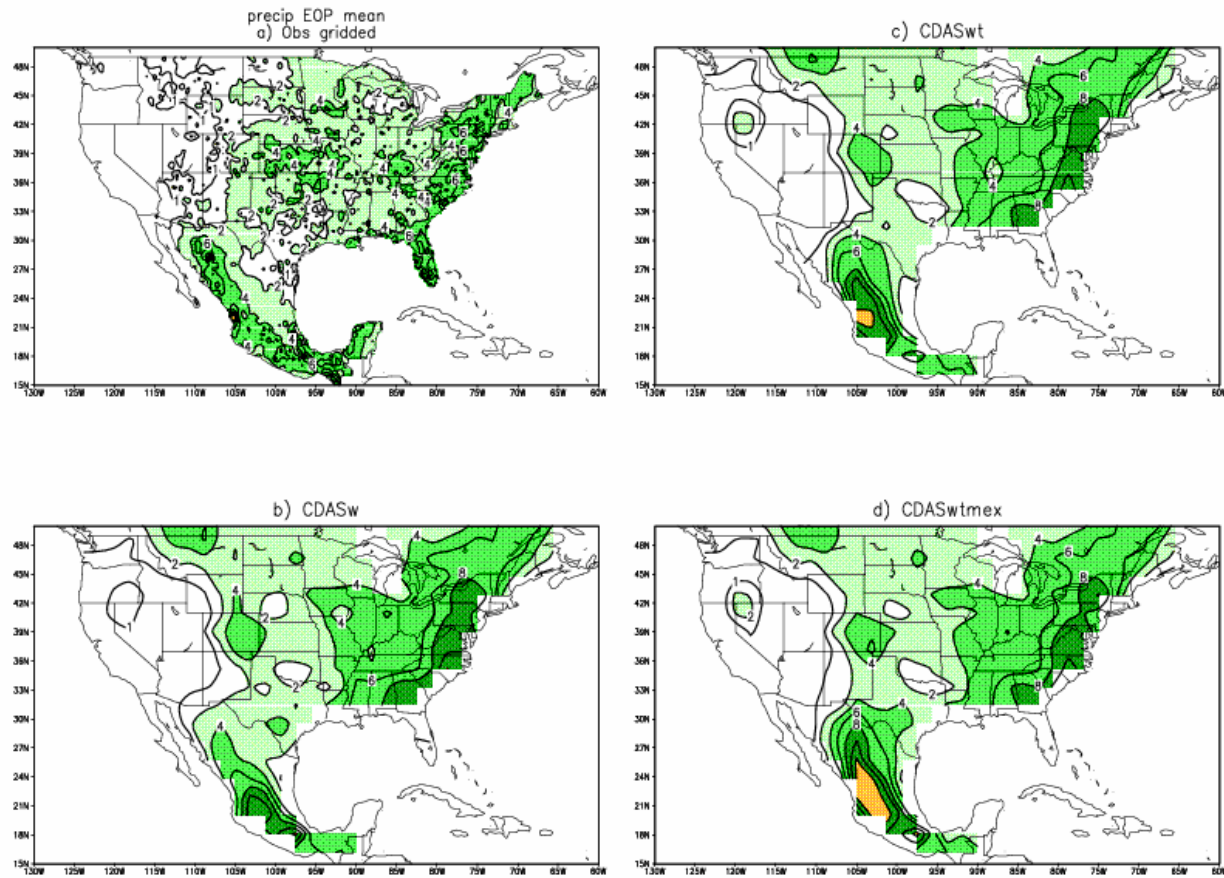


Figure 1: Precipitation averaged over the EOP period from (a) observed gauge analysis, (b) CDASw, (c) CDASwt and (d) CDASwtmex. Coontour intervals are 1 2 4 6 8 10 12 16 20 mm day⁻¹

Figure 1a shows a large band of precipitation over the western slopes of the SMO with a maximum about 8 mm day⁻¹. The maximum over the Southwest is 2 mm day⁻¹. During the EOP, heavy precipitation was also located over the Great Plains with a maximum about 4 mm day⁻¹. The CDASw shows better precipitation pattern over the monsoon region, but the maximum is shifted to the south. The mean P for all CDAS runs with and

without soundings are too dry over western Arizona. This is a common problem for low resolution models. The mean precipitation patterns for the CDASwt and CDASwtmex are similar. They show a band of heavy rainfall extending from the coastal region along 21°N to the central Mexico. None of the CDAS experiments capture the P maximum over the Great Plains.

The coarse resolution T62 model is not able to take advantage of additional soundings along the Gulf to improve moisture transport over that region. Figure 2 shows the vertically integrated moisture fluxes averaged over the EOP period, which should be compared with the operational GDAS. The GDAS has the resolution of 50 km and is able to resolve the Gulf of California. The CDASw captures the low level jet from the Great Plains (GPLLJ) with a broader maximum due to coarse resolution. The CDASwtmex with soundings over the Southern Plains shows a similar GPLLJ as the CDASw. The CDASwt without soundings over the Southern Plains shows a stronger GPLLJ. This indicates that the soundings over Texas improve the analyses. None of CDAS fluxes captures the low level jet from the Gulf of California. The GDAS indicates that the moisture is transported into the Southwest largely from the Gulf of California with a weaker branch from the North Pacific. All CDAS means indicate that the fluxes come from the North Pacific. There is no transport from the Gulf of California to the Southwest. Even though all soundings along the Gulf of California (Puerto Penasco, Kino Bay, Los Mochis, Empalme and Mazatlan) are accepted by the system.

For the CDAS, most impact is concentrated over northern Mexico. The coarse resolution model is not able to take advantage of the soundings to improve the moisture transport over the Gulf of California.

Because of large impact is largely local. We decided to perform data impact study to use the meso scale 12-km EDAS in addition to the RCDAS as originally proposed.

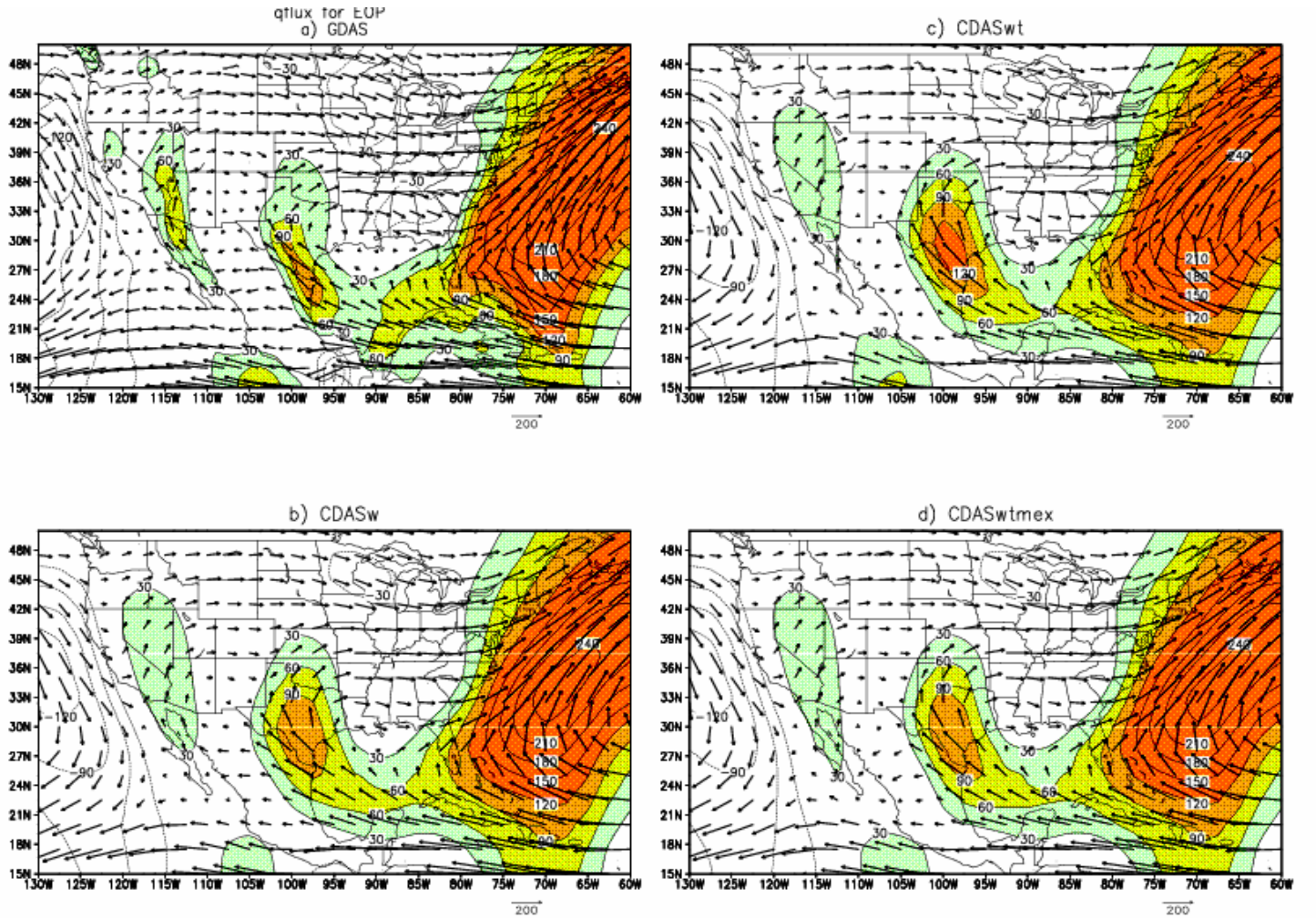


Figure 2: Vertically integrated moisture fluxes ($[q_u]$, $[q_v]$, vector) averaged over the EOP period from (a) the operational GDAS, (b) CDASw, (c) CDASwt and (d) EDASwtmex. The unit vector is 200 kg (ms)^{-1} . The $[q_v]$ also colored and contoured every 30 kg (ms)^{-1}

b) RCDAS

For RCDAS, the impacts of soundings on the large scale circulations, upper level jet are small. The large scale midlatitude flow patterns for the RCDASw and the RCDASwt are very similar. The largest impact is at the lower levels and is concentrated over the Gulf of California region, where the RCDAS has largest uncertainties. Figure 3 shows the vertically integrated moisture fluxes averaged over the EOP period for the RCDASwtmex and RCDASw, which should be compared with the operational EDAS and EDASwtmex. The RCDAS has a tendency to over analyze the low level jet from the Gulf of California

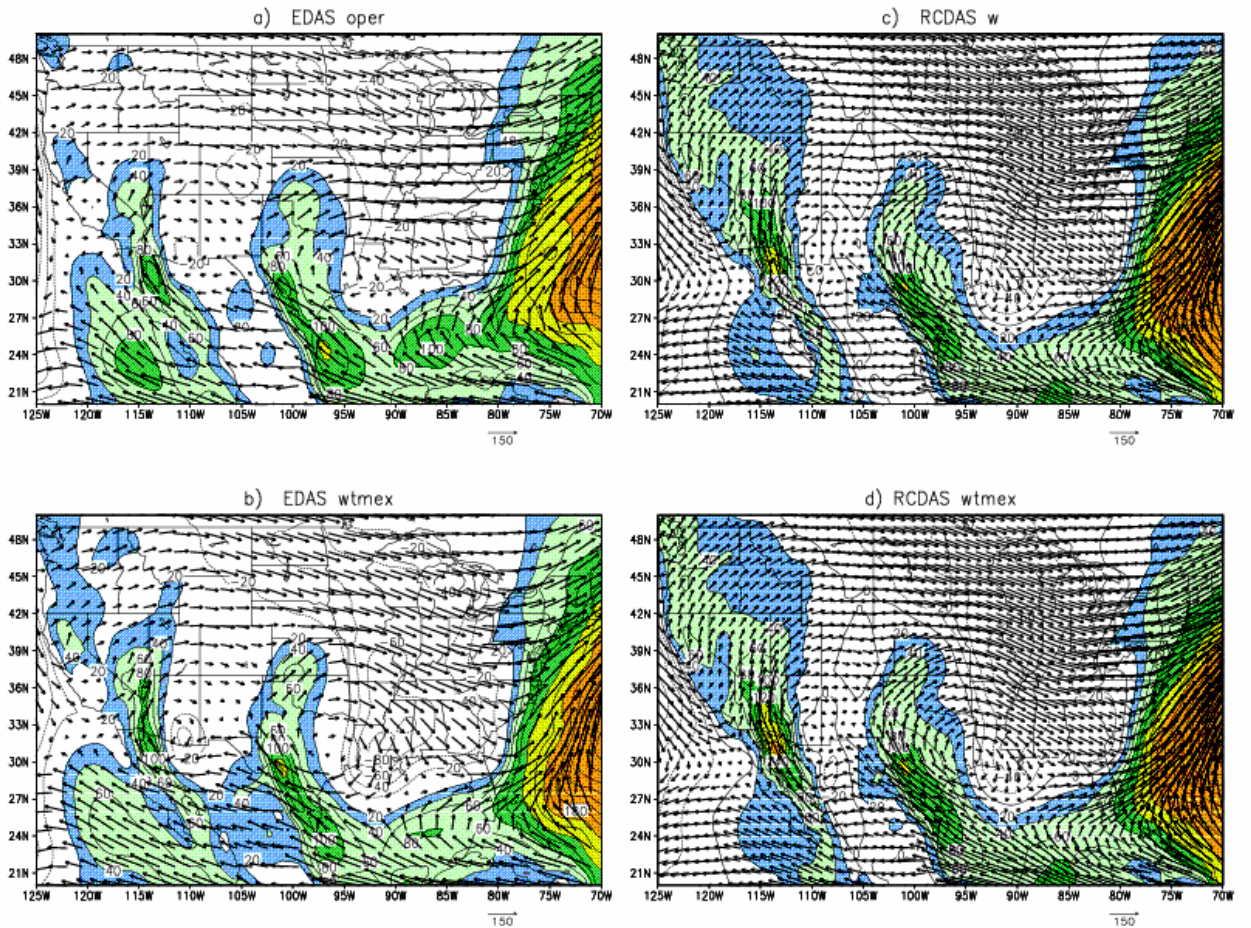


Figure 3: Vertically integrated moisture fluxes ($[q_u], [q_v]$, vector) averaged over the EOP period from (a) the operational EDAS, (b) EDASwtmex, (c) RCDASwt and (d)

RDASwtmex. The unit vector is 180 kg (ms)^{-1} . The [qv] also colored and contoured every 20 kg (ms)^{-1}

(GCLLJ). With soundings along the Gulf, the low level winds and specific humidity improve and the GCLLJ is substantially reduced in magnitude. The maximum of the vertically integrated meridional flux [qv] averaged over the EOP reduces from near 200 kg (ms)^{-1} to about 120 kg (ms)^{-1} which is close to the EDAS. The low level jet from the Great Plains does not change much with additional soundings. All shows a low level jet from the Gulf of Mexico to the Great Plains with a maximum about $80\text{-}120 \text{ km (ms)}^{-1}$ with the center located over the border between Texas and Mexico.

Overall, the inclusion of the NAME04 soundings improves the RCDAS. The impact is largely concentrated over northern Mexico and the Southwest. Therefore, the soundings over that region have the maximum impact. The RCDAS has its great uncertainties over the Gulf of California and the soundings improve the GCLLJ and flow over the Gulf of California. The RCDAS has always simulated the GPLLJ well and the impact of soundings there is small.

3. The impact of initial conditions of summer seasonal forecasts.

The CFS summer precipitation (P) forecasts over the United States have dry biases. Figure 4 shows the ensemble mean CFS forecasts for July-September (JAS) with the initial conditions in June averaged from 1982-2001. In comparison with the gauge based precipitation analysis, P over the Great Plains is about $1\text{-}1.5 \text{ mmday}^{-1}$ less than observations. This error is systematic and independent of the horizontal resolution.

To diagnose the errors, we compared the summer precipitation over North America for July-September (JAS) from a long term simulations of the Atmospheric Model

Intercomparison Project (AMIP) runs with the ensemble simulations (SIMU) initialized from the end of June for the period from 1991-2002.

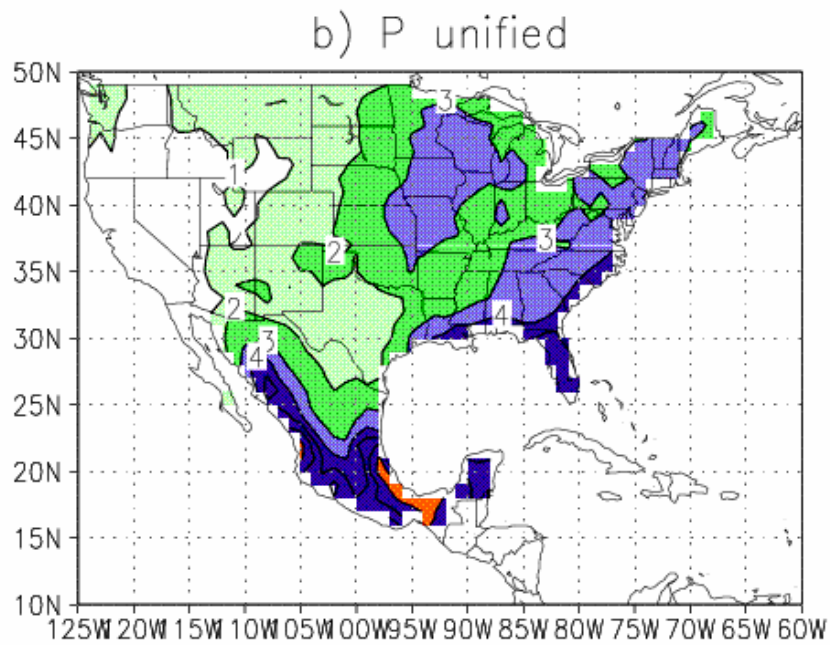
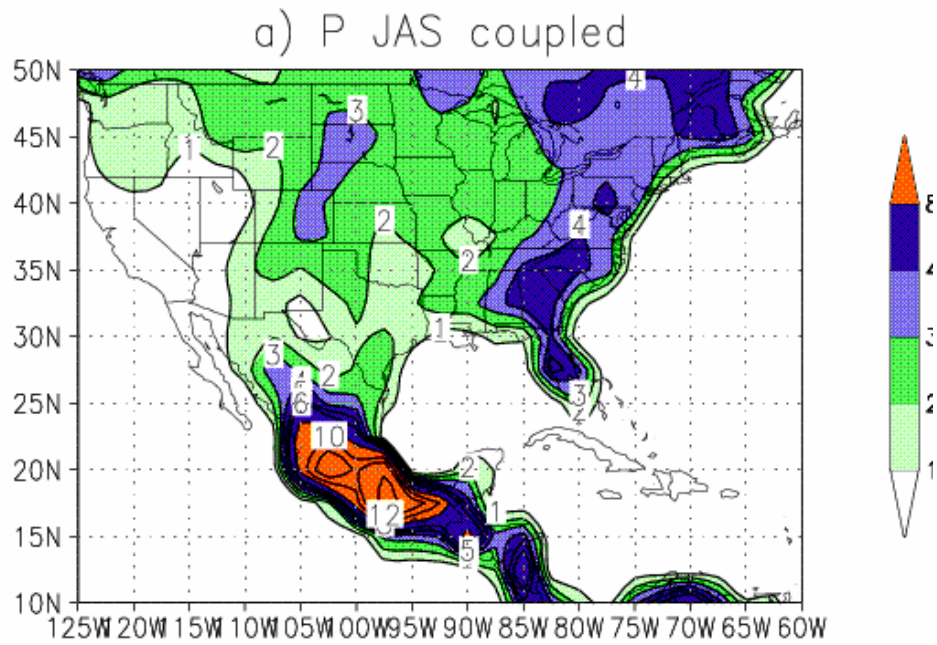


Figure 4: Precipitation for JAS averaged from 1982-2001 from (a) the CFS forecasts initialized in June and (b) the gauge based precipitation analysis.

Both types of simulations use the observed sea surface temperatures (SSTs) as boundary conditions, and hence, the differences come from the initial conditions. Experiments were performed using the NCEP Global Forecast System (GFS) T126L28 model with 28 vertical levels. The higher resolution model was used because this will be the future resolution of the GFS model.

Over the monsoon core region, the model captures the relationship between evaporation (E) and soil moisture well and the T126 model has enough horizontal resolution to simulate the moisture transport from the Gulf of California. The moisture divergence and E both contribute to P. Therefore, errors in E do not dominate errors in P.

Over the Great Plains, the model has dry and warm biases. These biases are larger in the AMIP runs in comparison with the SIMU. Two major model errors contribute to the

(1) The deep soil layer (10-200cm) is way too dry and does not have enough variability:

(2) The model does not capture the seasonally varying relationship between E and soil moisture at the top level 10cm (SM10cm).

E drops too sharply and too quickly during dry periods in spring. The AMIP runs have a large deficit in E at the beginning of July, while the SIMU runs have more realistic E values supplied by the initial conditions. The surface conditions deteriorate slow enough to have better seasonal mean summer E and P than the AMIP runs. These are also the reasons that the GLACE experiments based on the GFS model show very little relationship between the soil moisture variability and the precipitation variability over the United States.

III. Publications

- Mo, K. C., J. E. Schemm, R. W. Higgins, H. Juang and Y. Song 2004: Impact of Model Resolution on the Prediction of Summer Precipitation over the United States and Mexico, J. Climate In press.
- Mo, K. C., M. Chelliah, M. Carrera, R.W. Higgins and W. Ebizusaki 2004: Atmospheric transport as Evaluated from the NCEP Regional Reanalysis and Forecast Products. J. Hydromet in Press
- Mo, K. C., J. E. Schemm, H. Kim and R. W. Higgins 2005: Influence of initial conditions on summer precipitation over the United States and Mexico. J. Climate submitted.
- Mo, K. C., J. Woolen, R. W. Higgins and M. Carrera 2005: Impact of NAME04 Special Soundings on the CDAS2 and RCDAS systems J. Climate will be submitted on October 15,2005
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IV. Work plan and budget for FY 2006 (October 2005- September 2006)

Work Plan

1. RCDAS :

- Continue the RCDAS operation at the CPC;
- Develop applications using the RCDAS products

2. Data impact studies

- **Continue the study on the impact of the NAME 04 soundings:**

We will perform the EDASw and the EDASwt to identify the impacts of the NAME soundings based on different regional analyses. One important aspect is whether the impact of soundings is larger than the differences between the regional analysis systems. Even though both the EDAS of 2004 and the RCDAS were based on the Eta model, the data inputs were different. For example: the EDAS does not assimilate P over Mexico and adjacent oceans. The comparison will give us some insights on that.

- **Impact of SSTs.**

The operational analyses used the operational OI based daily sea surface temperatures in 2004. This SST data set was used for all data impact experiments

Recently, Dr. Xie is preparing a satellite and the in situ data based high resolution (0.25 degrees and 3 hourly) SST in supporting the NAMAP2 project. We will repeat the CDASw and the RCDASw with all NAME 04 soundings to study the impact of the SSTs.

- **Impact of P assimilation**

We will perform the RCDASw without the P assimilation to determine its impact and compare with the impact of the NAME04 soundings.

- **Forecast experiments**

One measure of the impact of the NAME04 soundings is to perform short range forecasts. In general, more accurate initial conditions should reduce the forecast errors in 1-3 days. We will perform 96 hour forecasts with initial conditions from CDASw and the CDASwtmex to determine the impact of soundings on the global forecasts. We also will perform 84 hour forecasts with initial conditions from EDASw and the EDASwtmex to determine the impact of soundings on the regional forecasts on the monsoon rainfall and related features. The reason to use the EDAS is that the RCDAS has problems with the GCLLJ and this is a monsoon related study. The EDAS also has higher resolution so it is expected to capture the synoptic features better.

- **Impact on summer seasonal precipitation forecasts**

We have demonstrated that the GFS with a two layer soil model is not able to simulate the interaction between soil moisture and evaporation. Recently, Ken Mitchell's group implemented the Noah LSM coupling with the GFS model. With collaboration with his group, we will perform simulations for 2004 using the new surface model and with initial conditions from the CDAS2 with and without the